

WHAT WE CLAIM IS:

1. A method for determining characteristics of a system under test (SUT) comprising the steps of:

5 providing, by an excitation means, a time-varying current-mode electrical excitation to a system under test, which time varying signal comprises a periodic or quasi-periodic waveform;

detecting, by a detection means, the conjugate electrical response elicited from the system under test by the excitation;

10 converting the detected response from an analog signal into a digital response signal by means of an analog-to-digital conversion means, controlled by a synchronous sampling clock controlling means; and

performing at least one predetermined analysis of the digital response signal to determine at least one characteristic of the system under test.

2. The method of Claim 1, wherein the characteristics of the excitation signal
15 are adjustable, said characteristics including:

the amplitude of the excitation that is comprised of one or more waveforms that are generated either by analog circuitry means, or digital circuitry means;

20 the duration of each portion of a waveform, where a portion of a waveform is bounded at each of its end points by either zero crossing corresponding to a change of relative polarity, or by a zero amplitude value;

the relative phase, with respect to a separate reference clock signal, of each waveform comprising the excitation signal.

3. The method of Claim 1, wherein the system under test may be one of:

25 a chamber that is suitably disposed to receive an analyte and is equipped with at least two electrical members, at least one of which serves as a collector electrode and at least another serves as an emitter electrode; and

an electrochemical accumulator, comprising at least one cell, which is provided with terminals to which excitation and sense test signal connections can be effected.

4. The method of Claim 1, wherein the analog-to-digital conversion means is an Analog to Digital converter controlled by a separate synchronous sampling-clock, said sampling clock being responsive to a separate clock source operative in accordance with a pre-determined sampling schedule.

5 5. The method of Claim 1, wherein the excitation may take the form of either a current or a voltage and the time-varying excitation signal may comprise, in any order, either at least one of, or a consecutively emitted plurality of any combination of, the following waveforms:

a cycle comprising portions, which may occur in either order, of a period of discharging, that is, negative, current, followed by a period of zero current, the duty-cycle ratio of each of which cycles may be adjusted independently from cycle to cycle, wherein the boundary point between said portions represents the end point and beginning point of the leading and trailing waveform portions respectively;

15 a cycle comprising portions, which may occur in either order, of a period of charging, that is, positive, current, followed by a period of zero current, the duty-cycle ratio of which cycles may be adjusted independently from cycle to cycle, wherein the boundary point between said portions represents the end point and beginning point of the leading and trailing waveform portions respectively; and

20 a cycle comprising portions, which may occur in either order, of a period of charging, that is, positive, current followed by a period of discharging, negative current, the duty-cycle ratio of which cycles may be adjusted independently from cycle to cycle, wherein the boundary point between said portions represents the end point and beginning point of the leading and trailing waveform portions respectively.

6 The method of Claim 1, wherein the electrical excitation is a periodic time varying signal comprising one or more whole waveform cycles having substantially identical amplitude, polarity and duration characteristics.

7. The method of Claim 1, wherein the electrical excitation is a quasi-periodic time varying signal comprising a plurality of waveform cycles, at least two of which cycles have at least one distinctly different characteristic, which characteristics may include the amplitude of a part-cycle or the duration of a part-cycle, or the relative polarity of corresponding part-cycles.

8. The method of Claim 1, wherein the time-varying current excitation signal exhibits a plurality of abrupt discontinuities and comprises one or more waveforms, which waveform may be any of:

a rectilinear waveform, exhibiting a leading edge that constitutes an abrupt amplitude transition, followed by a substantially constant-amplitude portion, followed by another abrupt amplitude transition representing a trailing edge;

a ramping waveform comprising, in either order, an abrupt amplitude step representing an abrupt amplitude and a portion whose amplitude varies with time in a linear fashion, thus exhibiting a constant, but non-zero, first derivative with respect to time; and

a triangle waveform comprising two distinct adjacent ramping segments each exhibiting a separate non-zero slope and whose adjacent ends are coincident at a point whereat the value of the slope of the waveform exhibits an abrupt transition;

9. The method of Claim 1, wherein, over the course of a test event, the time average of the excitation current is non-zero so that either, the DUT is excited with a net positive current representing charging, the DUT is excited with a net negative current representing discharging.

10. The method of Claim 1, where in the range of achievable excitation amplitudes may be sufficiently wide to allow both:
non-invasive testing, wherein no irreversible changes are wrought on the system or device under test; and

invasive testing, wherein irreversible changes are wrought on the system or device under test.

11. The method of Claim 1, wherein at the step of performing, a point-to-point averaging technique is applied as follows to reduce noise in the data:

when response data obtained from the system under test indicates, by the lack of any slowly varying offset/bias component in the response signal, that it is substantially in a state of equilibrium, noise reduction is achieved by performing point-to-point averaging directly on corresponding data points obtained from a plurality of consecutive response cycles, to obtain a single cycle of averaged data points; or

when response data obtained from the system under test indicates by the presence of a slowly varying offset/bias component that exhibits a substantially constant slope over a plurality of response cycles, noise reduction is achieved by first determining the nature of the slowly-time-varying offset, then removing, by subtraction, the contribution of said offset from each response data point to obtain a series of compensated data points, and finally performing point-to-point averaging directly on the compensated data point obtained during said plurality of consecutive response cycles, to obtain a single cycle of averaged data points.

12. The method of Claim 3, wherein at least one collector electrode and one emitter electrode each also serve as sense electrodes.

13. The method of Claim 3, wherein additional electrical members are provided that serve as sense electrodes distinct from the collector and emitter electrodes.

14. The method of Claim 3, wherein the sense electrodes are suitably positioned with respect to the separate excitation electrodes, to function in the manner of a Kelvin sense connection.

15. The method of Claim 1, wherein the chamber contains, in addition to the analyte, a separate medium provided to permit the flow of electric current between the analyte and the other electrodes.

16. The method of Claim 1, wherein the system under test corresponds to an electrochemical accumulator and the excitation comprises one or more complex pulse-type excitation signals characterized by alternating periods of discharging current and zero current to the cell.

5 17. The method of Claim 1, wherein the systems under test comprises an accumulator, and the conjugate response signal represents the time-varying cell polarization voltage developed between the terminals of the accumulator due to a current mode excitation, and said time-varying cell polarization voltage information is analyzed to determine at least one characteristic of the accumulator, which characteristic may
10 include:

the relative state of charge of the accumulator;

the relative state of health of the accumulator;

the relative degree of passivation exhibited by the accumulator;

15 the real component of the accumulator's complex impedance or conductance, as a function of frequency;

the imaginary component of the accumulator's complex impedance or conductance, as a function of frequency; or

a specific failure or error condition in the accumulator.

20 18. The method of Claim 1, wherein the value of the first time-derivative of the time-varying polarization voltage response is computed for at least one portion of the time-dependent polarization voltage data, and used to determine at least one characteristic of the accumulator, which characteristic may include:

the relative state of charge of the accumulator;

the relative state of health of the accumulator;

25 the relative degree of passivation exhibited by the accumulator;

a specific failure or error condition in the accumulator.

19. The method of Claim 1, wherein at the step of performing the analysis may be any of:

the determination of the presence, at a minimal concentration, of a least one particular analyte or chemical substance contained within a test chamber;

5 the determination of the concentration of at a least one particular analyte or chemical substance contained within a test chamber; and

the determination of the quantity of at least one particular analyte or chemical substance contained within the test chamber; and

10 wherein the excitation is periodic, the calculation of the Fourier or LaPlace transforms of the digitally represented excitation and response data, which transforms may be further manipulated to yield the corresponding complex impedance spectrum;

the extraction of information from results of at least one previous analysis, allowing a characterization of at least one equivalent circuit model that describes the underlying electrochemical system;

15 the determination of asymmetries between the positive and negative parts of the response waveform, or sets of part-cycles that have been subjected to point-by-point averaging to achieve noise reduction, said asymmetries representing hysteresis effects indicating disparities of forward and backwards reactions occurring within the analyte;

the determination of amplitude extrema contour curves;

20 the determination of slowly changing bias conditions within the DUT, through the application of sliding-average or other low-pass filtering methods;

the determination of transitions between linear and non-linear response regimes within the DUT, and therefrom determine reaction-point thresholds; and

25 the extraction of information from results of at least one previous analysis, allowing a characterization of at least one underlying electrochemical process that occurs within the electrochemical system in response to the excitation.

20. The method of Claim 3, wherein the analyte has been modified to incorporate an electrochemically sensitive marker component.

21. An apparatus disposed to perform electrical and electrochemical measurements comprising at least:

- 5 an excitation driver;
- an excitation receiver;
- a response sensing preamplifier;
- a synchronous sampling means; and

10 suitable means of interconnection to a system or device under test, whereby an excitation signal may be forced to flow through said system or device, and the resultant conjugate response signal detected and conveyed to the preamplifier operatively connected to a synchronous sampling means.

22. The apparatus of Claim 21, wherein the excitation driver is either:
disposed to emit a current-mode signal, while the excitation received is disposed
15 to receive a current-mode signal, and the preamplifier is disposed to detect a voltage-mode response; or

disposed to emit a voltage-mode signal, while the excitation received is disposed to receive a voltage-mode signal, and the preamplifier is disposed to detect a current-mode response;

20 23. The apparatus of Claim 21, wherein the synchronous sampling means operates according to a pre-determined sampling schedule such that:

sampling may commence concurrently with an abrupt excitation transition and proceed according to a predetermined set of time delay values;

25 sampling may commence, or re-commence, at any boundary point between the portions of an excitation cycle and proceed therefrom according to a predetermined set of time delay values; and

sampling may be preformed on both the excitation signal and the response signal.

24. The apparatus of Claim 21, wherein a chamber is disposed to receive an analyte, and said chamber is equipped with electrodes suitably disposed for providing an excitation signal to, and detecting a response signal from, the analyte.

25. The apparatus of Claim 23, wherein the electrodes within a test chamber
5 are configured to provide a Kelvin connection with respect to the analyte.